TC TORNADOES and SPC FORECASTS in TC SITUATIONS

Part ONE: Basic Concepts

Roger Edwards & Harry Weinman

Storm Prediction Center
Norman, Oklahoma

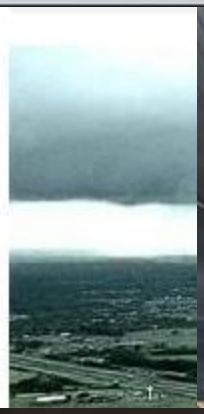
METR 4403/5403: Applications of Meteorological Theory to Severe-Thunderstorm Forecasting

TC HERMINE TORNADOES HIT DALLAS

Tornadoes touch down in Dallas

By **the CNN Wire Staff**

September 9, 2010 -- Updated 0046 GMT (0846 HKT)



TC MUJIGAE TORNADOES HIT CHINA

Seven dead and 223 injured as tornadoes brought by Typhoon Mujigae ravage China's Guangdong province

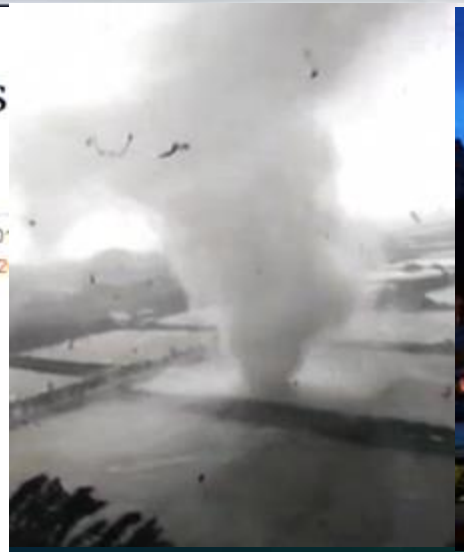
Mimi Lau
mimi.lau@scmp.com

PUBLISHED : Monday, 05 October, 20
UPDATED : Tuesday, 06 October, 2

One of the tornadoes that struck Guangdong province on Sunday. Photo: SCMP Pictures

At least seven people were killed and 16 were reported missing in Guangdong on Sunday after Typhoon Mujigae and the tornadoes it generated ravaged the province, cutting power, water supplies and communications.

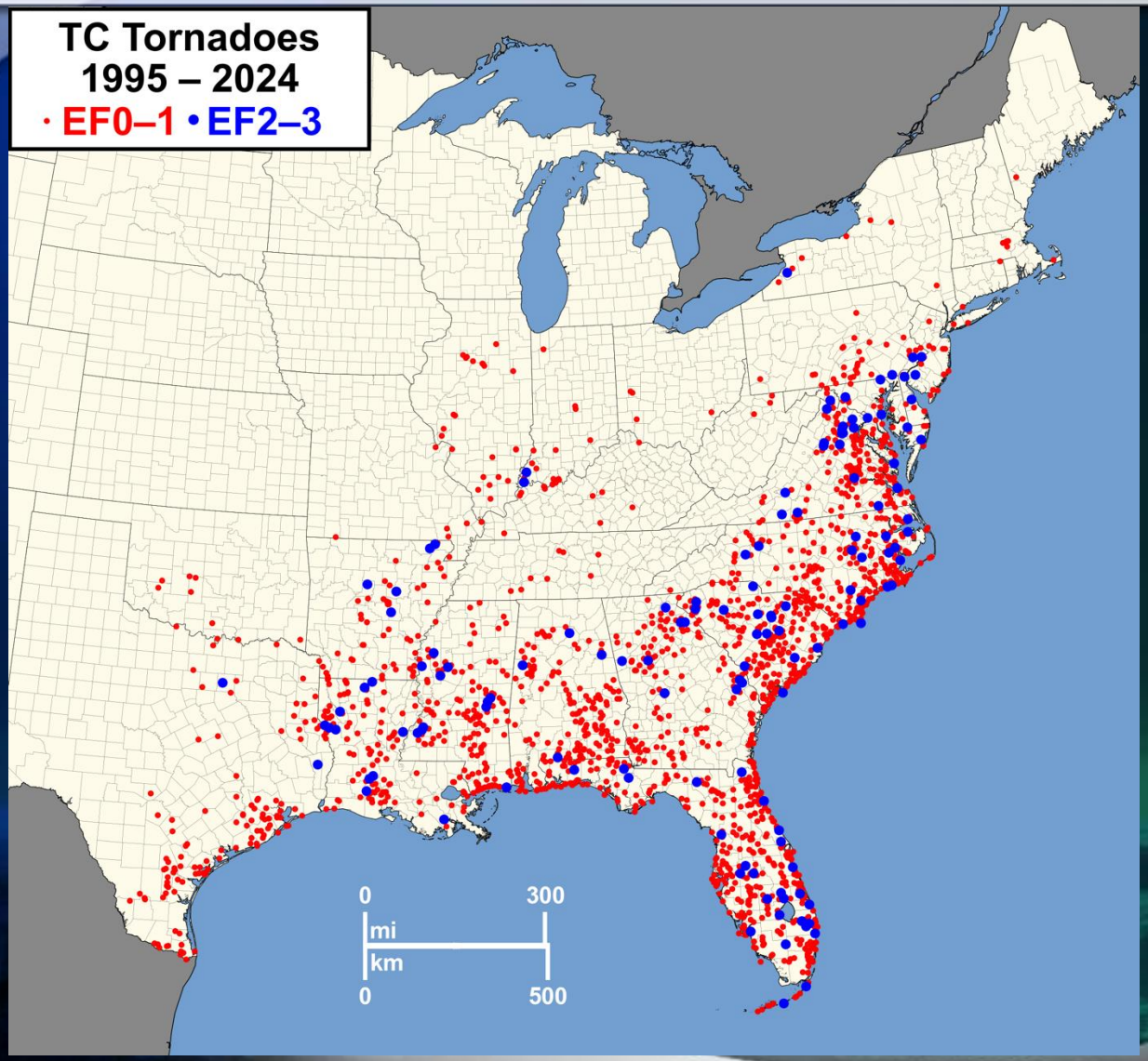
Six killed by 2 tornadoes (3 each).
One killed on boat in typhoon itself.
Image courtesy South China Morning Post.



TC TORNADO FACTS & CLIMATOLOGY

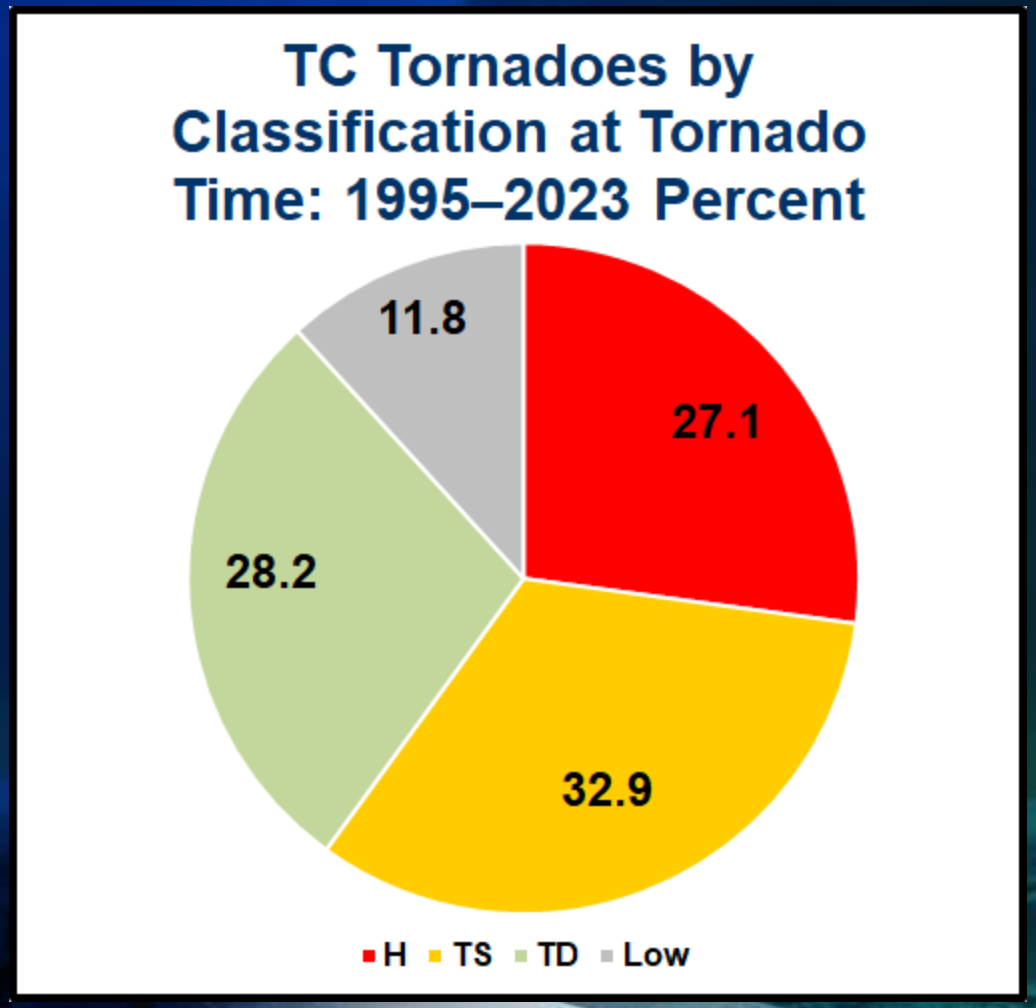
- MOST COMMON IN <50-kt WIND AREA
- MOST COMMON NNW-NE-SE OF CENTER
- MOST COMMON AND DAMAGING FROM MINI-SUPERCELLS (EF0-EF3, TWO F4S SINCE 1950)
- OCCASIONALLY REPORTED FROM NON-SUPERCELL RADAR FEATURES (WEAK – EF0-EF1)
- SHARP DECREASE >500 km FROM COASTS
- MORE COMMON DIURNALLY
- OCCUR OVER WATER AND CAN MOVE ASHORE
- OCCUR IN EVERY STAGE OF CLASSIFICATION
- DETAILED DISCUSSION IN EDWARDS (2012), EJSSM

TC TORNADO FACTS & CLIMATOLOGY



Geography of TCTOR events

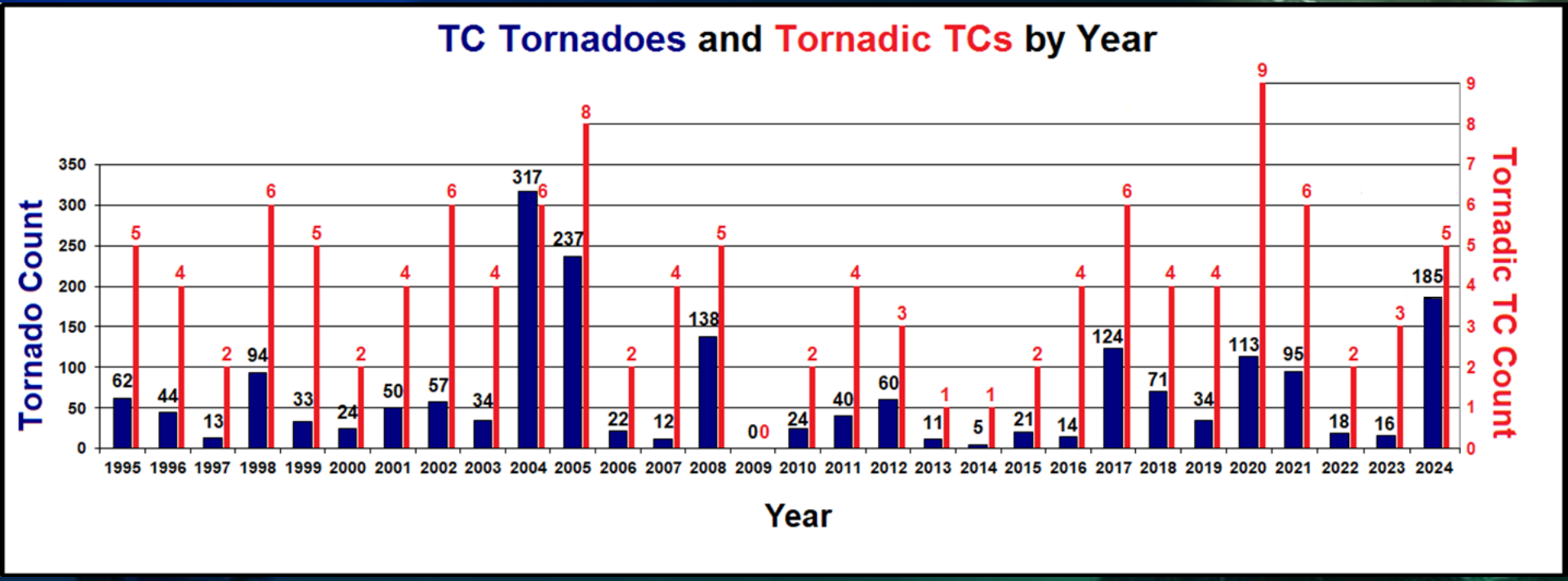
TC TORNADO FACTS & CLIMATOLOGY



TCTOR DATA: TC STRENGTH AT TORNADO TIME (from HURDAT)

TC Category	Max Sus. Wind (mph)
MH 5	>155
MH 4	131-155
MH 3	111-130
MH 2	96-110
MH 1	74-95
TS 0	39-73
TD -1	<38
N -2	Not classified

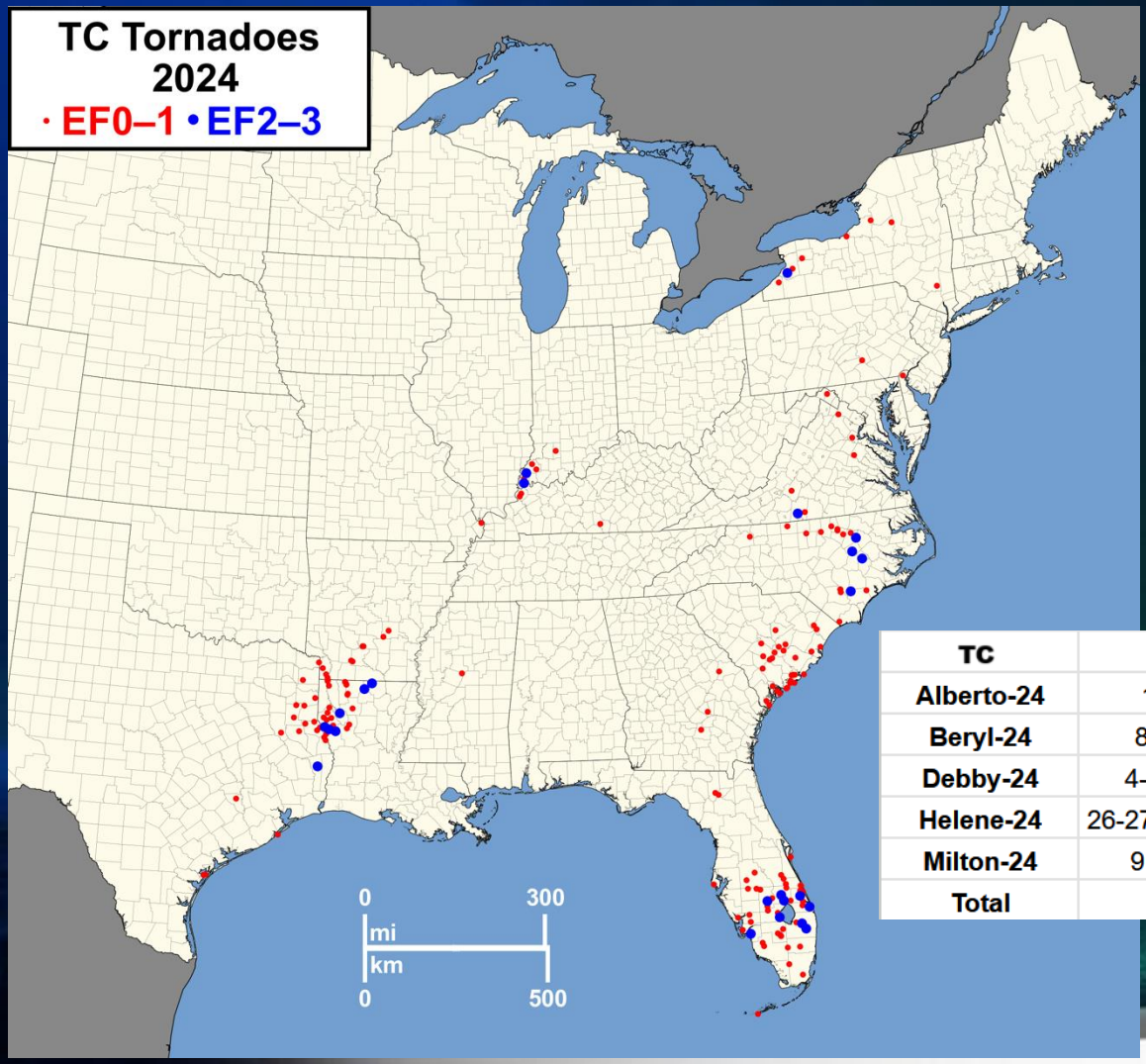
TC TORNADO FACTS & CLIMATOLOGY



Highly variable year-to-year in WSR-88D era

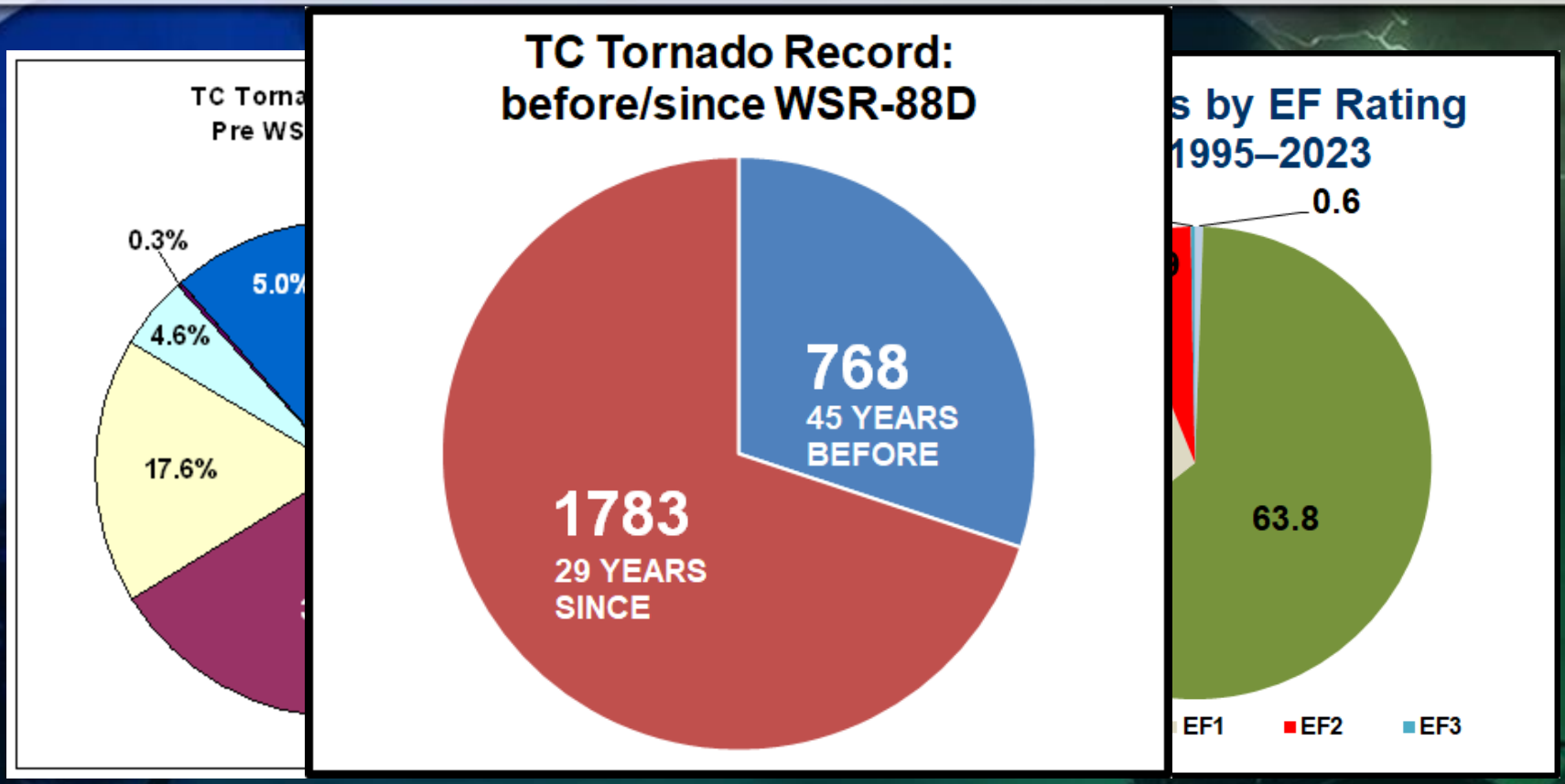
TC TORNADO FACTS & CLIMATOLOGY

2024: Efficient, Deadly, Costly



TC	Dates	Total	EFU	EF0	EF1	EF2	EF3	Fatal	Injury
Alberto-24	19 June	3	0	2	1	0	0	0	0
Beryl-24	8-10 July	68	3	11	44	9	1	2	4
Debby-24	4-9 August	30	0	15	12	2	1	1	2
Helene-24	26-27 September	39	1	22	14	1	1	2	16
Milton-24	9 October	45	4	7	25	6	3	6	14
Total		**185**	**8**	**57**	**96**	**18**	**6**	**11**	**36**

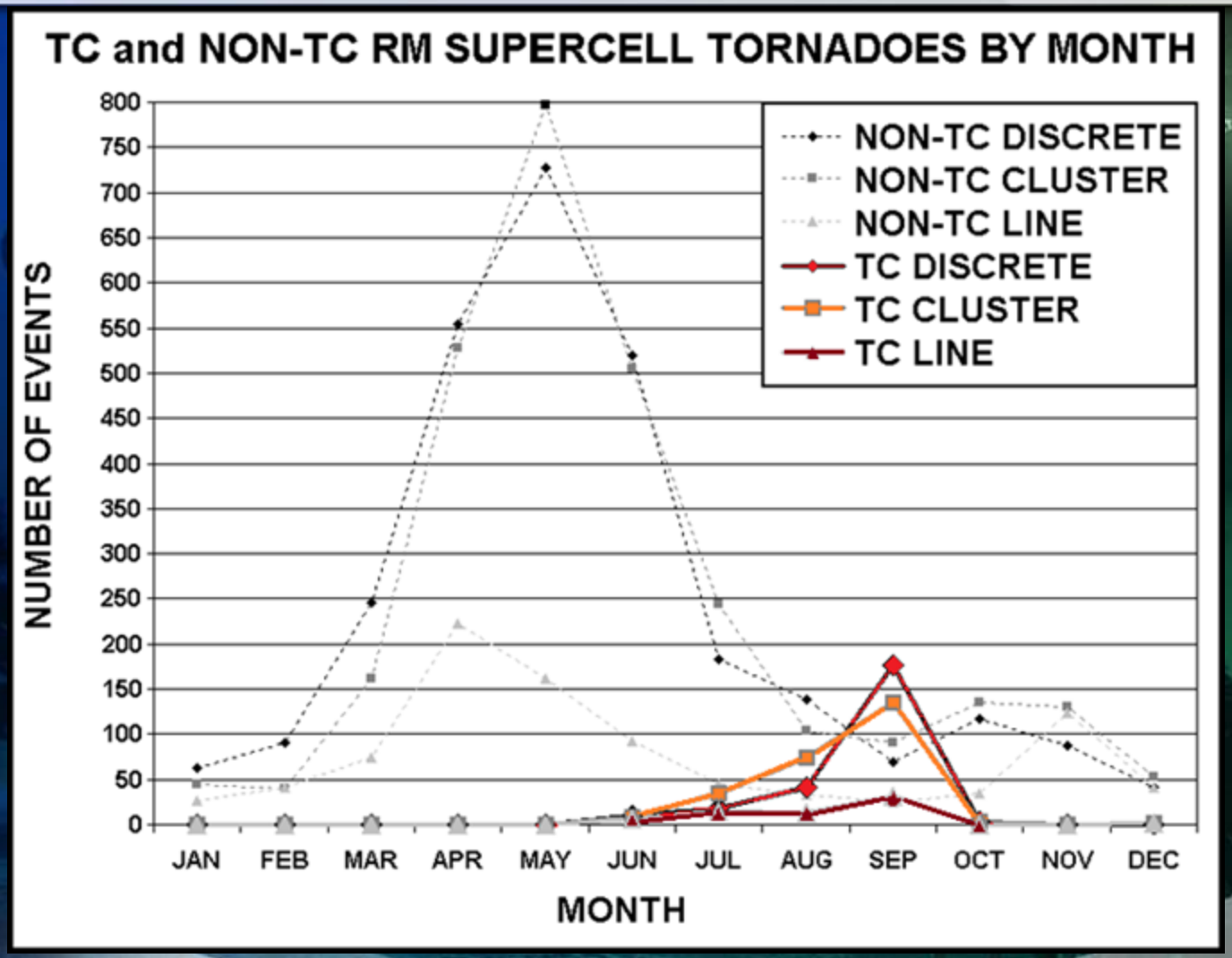
TC TORNADO FACTS & CLIMATOLOGY



88D era: Many more weak TC tornado reports, Many more TC tornado reports PERIOD!

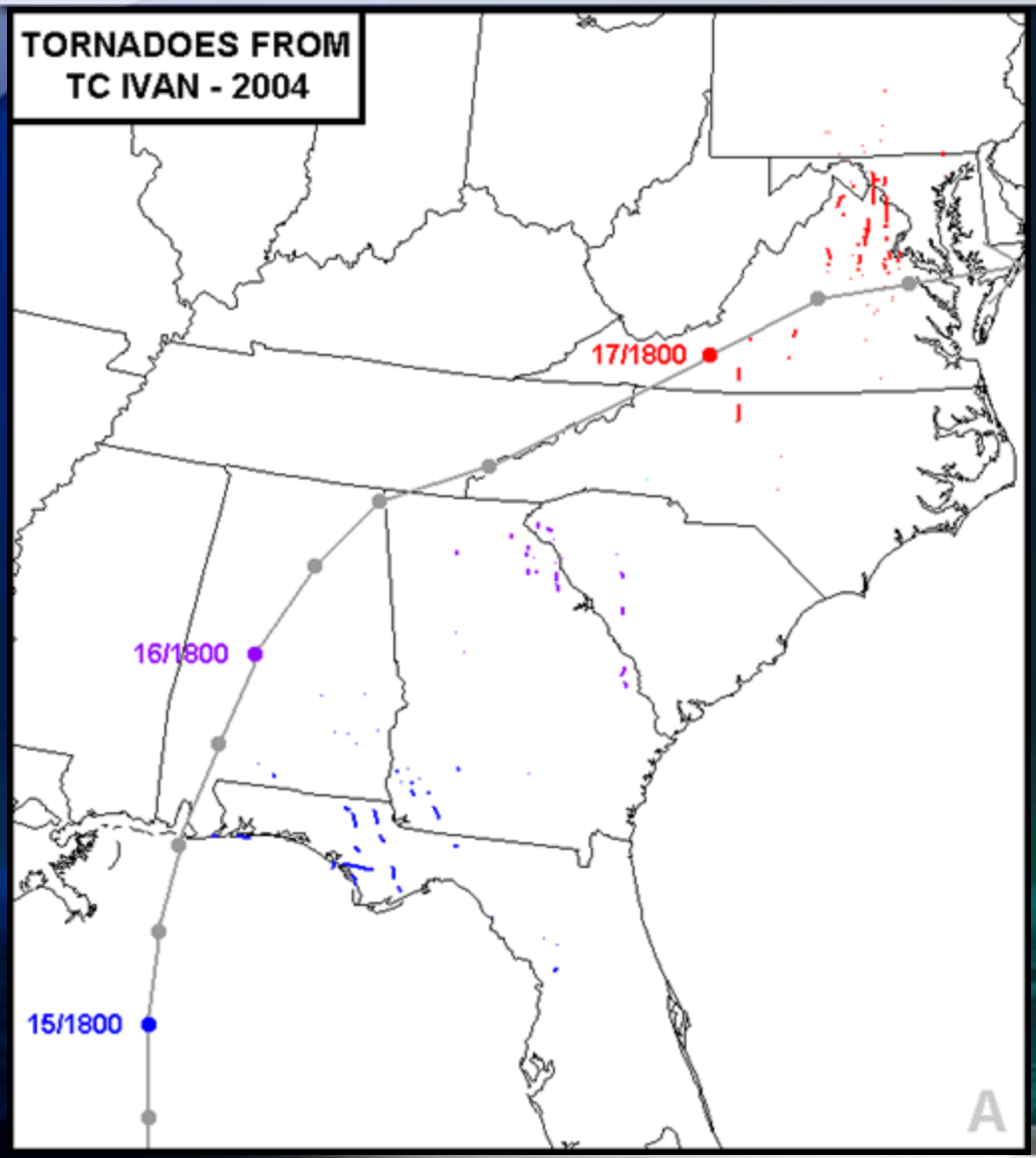
Pre-TCTOR data from Schultz and Cecil (2009)

TC TORNADO FACTS & CLIMATOLOGY



data from Edwards et al. (2012)

TC TORNADO FACTS & CLIMATOLOGY



...and the single-storm winner is

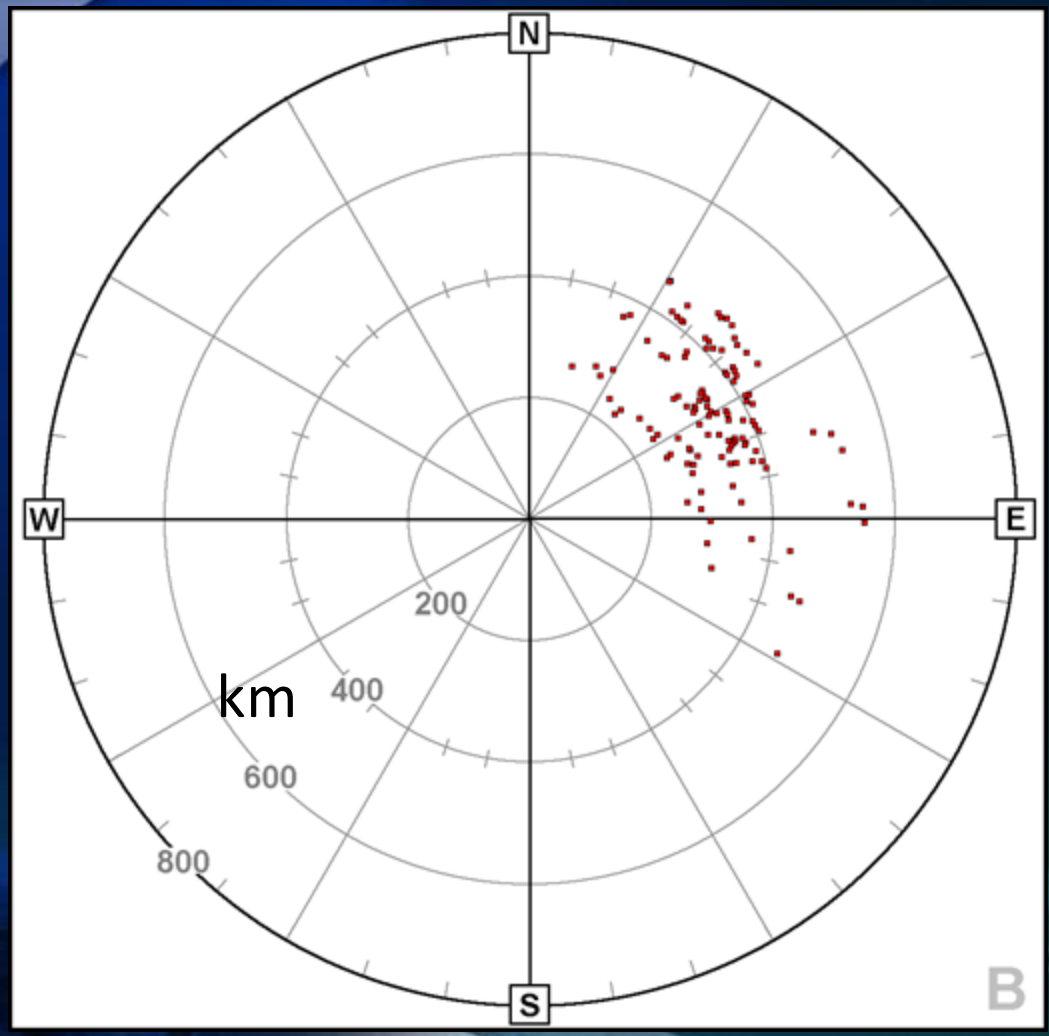
IVAN

118 in 3-DAY CYCLE

MAY HAVE SET ALL-TIME RECORD

(115 – BEULAH 1967)

TC TORNADO FACTS & CLIMATOLOGY



3 DAYS COMBINED

TOTAL TORNADO DISTRUBITION FROM CENTER FOR IVAN (2004)

VERY TIGHT!

TC TORNADO FACTS & CLIMATOLOGY

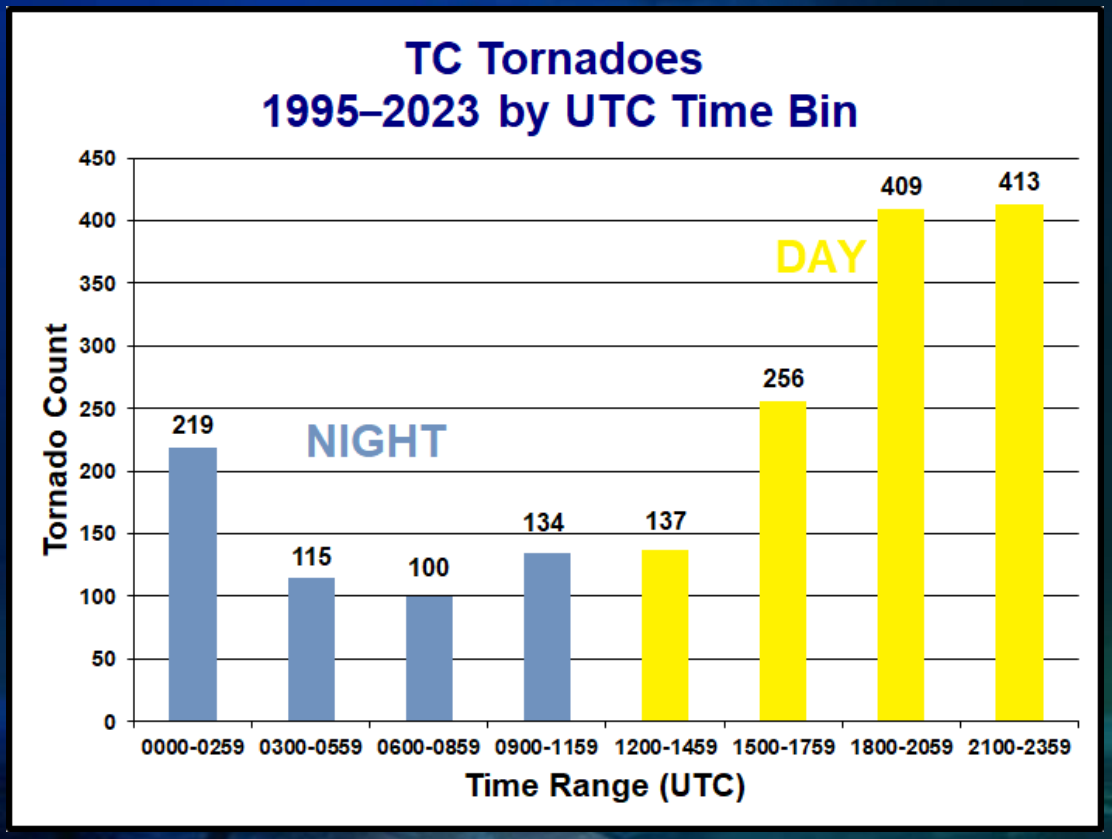
TROPICAL CYCLONE	YEAR	TORNADO REPORTS
H IVAN	2004	118
H BEULAH	1967	115
H FRANCES	2004	103
H RITA	2005	97
H BERYL	2024	68
H KATRINA	2005	59
H ANDREW	1992	56
H HARVEY	2017	52
TS FAY	2008	50
H GUSTAV	2008	49

TOP-10 LIST

From TCTOR and pre-1995 formal references

Peak classification

CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS

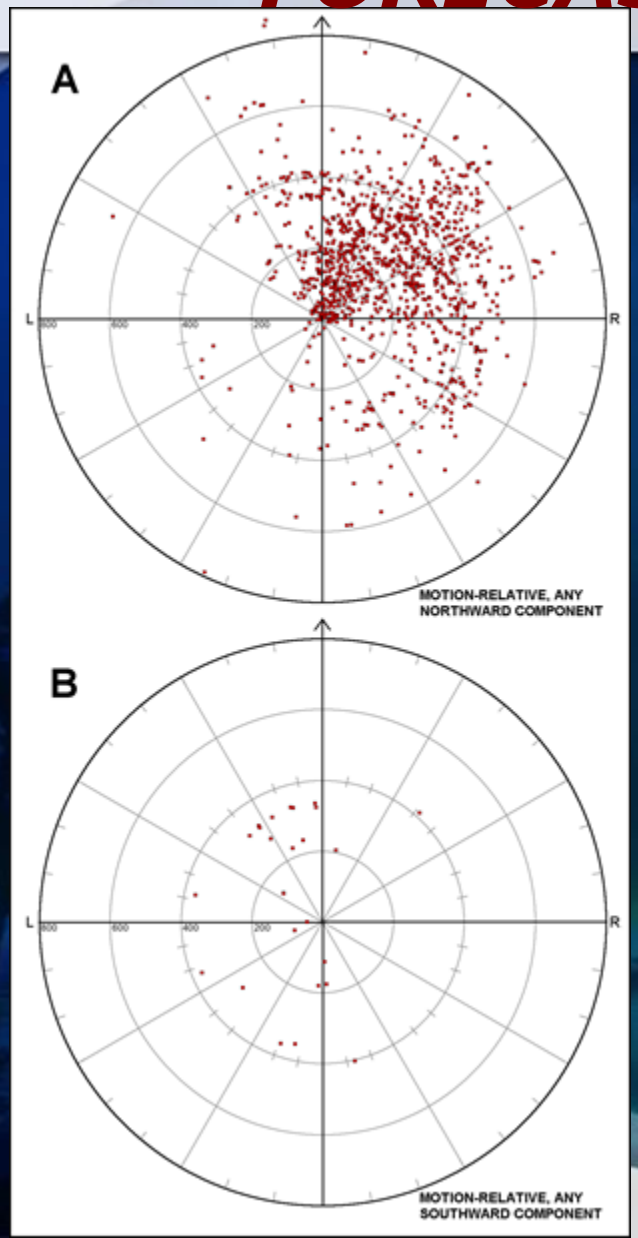


DIURNAL TREND:

In moist-adiabatic lapse rate environment, even subtle thermal warming under cloud cover greatly increases CAPE.

Dry air intrusions into TCs allow for gaps between convective rainbands

CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS

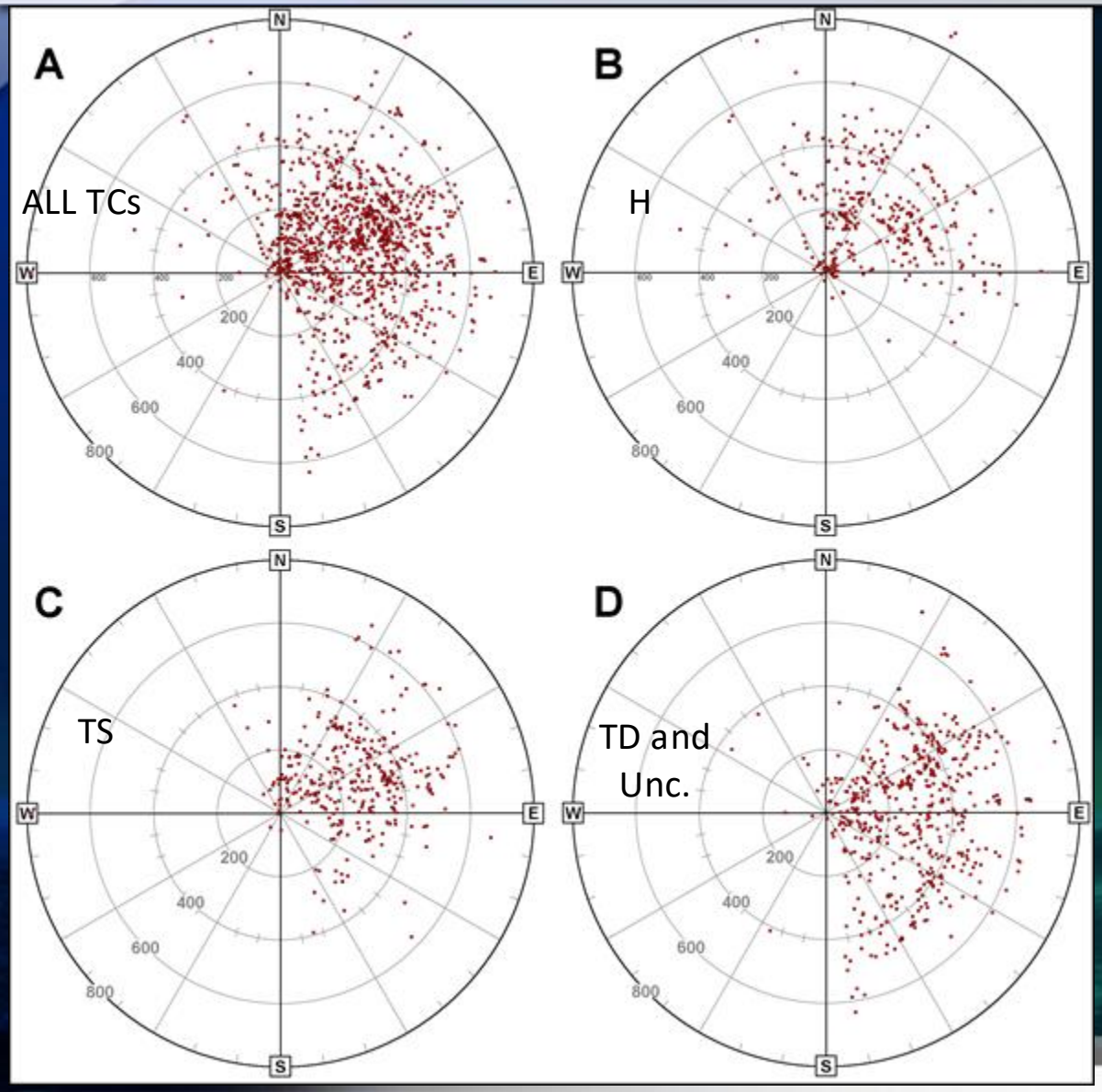


Motion-relative AZRAN of TCTOR events from center: **Northward translation component**

HOW MOTION-RELATIVE FAILS

Motion-relative AZRAN of TCTOR events from center: **Southward translation component**

CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS

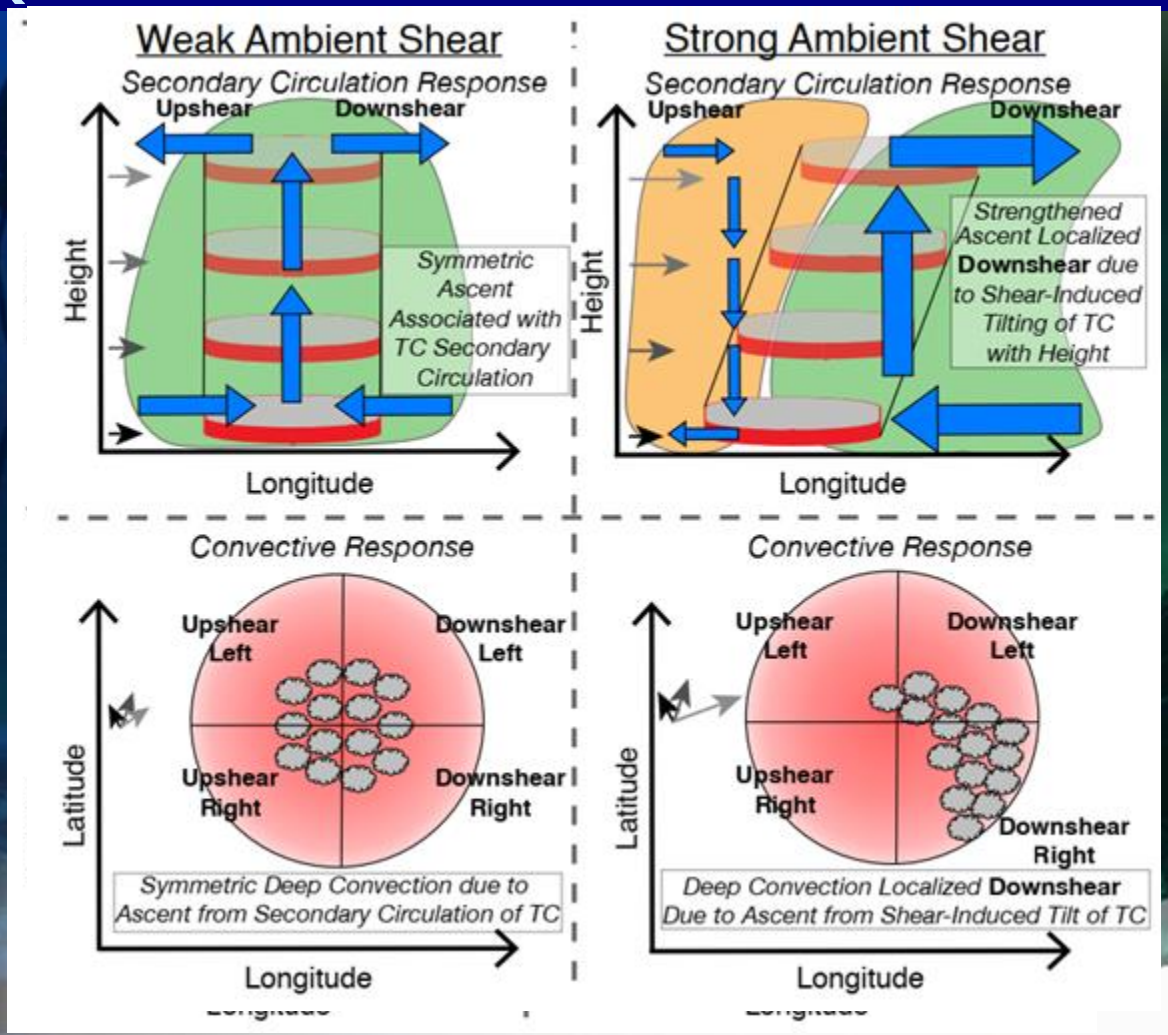


Tornadoes more common in SE sectors as TCs weaken…WHY?

…partly due to that sector's being over water when most are mature hurricanes!

CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS

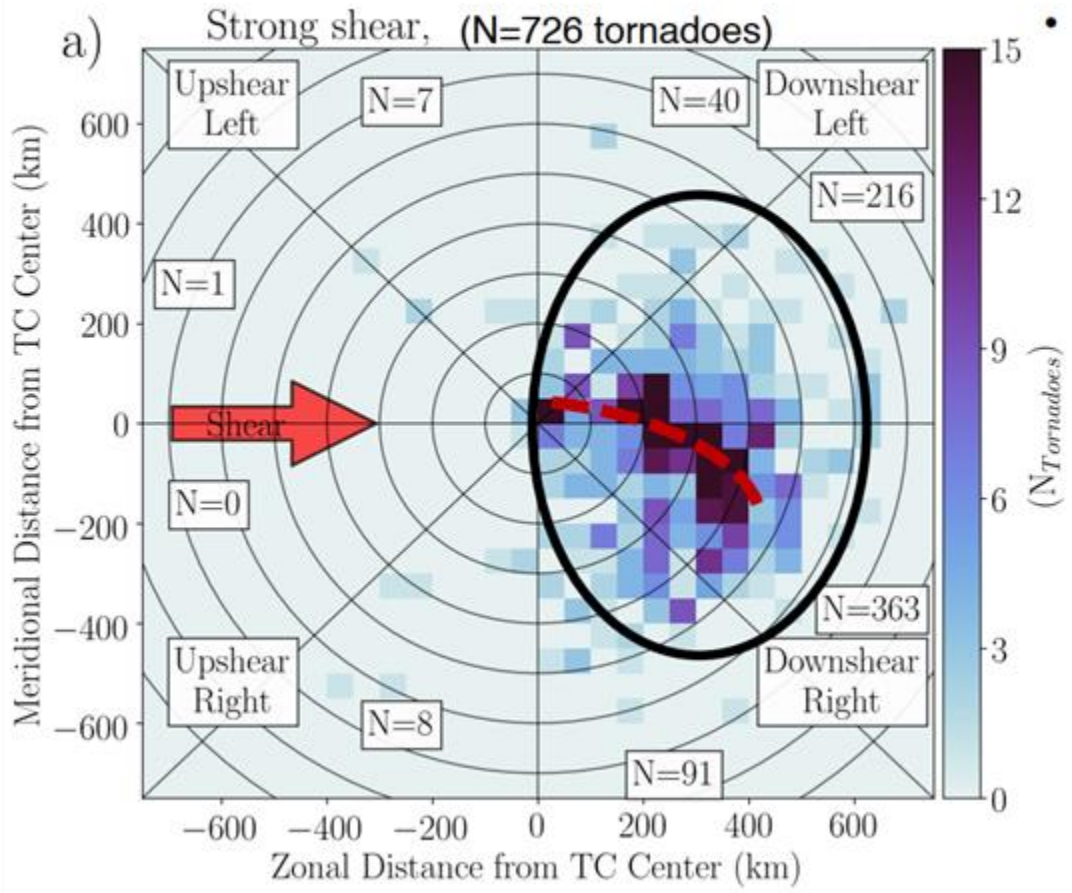
Shear-vector-relative distributions with physical basis (Schenkel et al. 2020 – October 2020 WaF)



CLIMATOLOGICAL APPLICATION TO FORECASTING CONCEPTS

Shear-vector-relative distributions with physical basis (Schenkel et al. 2020 – October 2020 WaF)

Tornado Frequency and Location in Strongly Sheared TCs



- Strongly sheared TCs associated with:
  1. Majority of tornadoes (57%);
  2. Nearly all tornadoes in **downshear half** of TC.

TC TORNADO FORECASTING CONCEPTS

Shifting from climatology-based and empirical to

INGREDIENTS-BASED THINKING

For supercells in midlatitude systems and tropical cyclones!

- **MOISTURE:** usually no problem
- **INSTABILITY:** helps to have diurnal heating with large antecedent BL theta-e to offset weak lapse rates aloft
- **(source for) LIFT:** Spiral bands, embedded boundaries concentrate threat on mesoscale and smaller – **FREQUENT HAND ANALYSIS is CRUCIAL!**
- **VERTICAL SHEAR:** Peak hodographs in climatologically favored N-NE-SSE sector, which is DOWNSHEAR

Edwards 2012

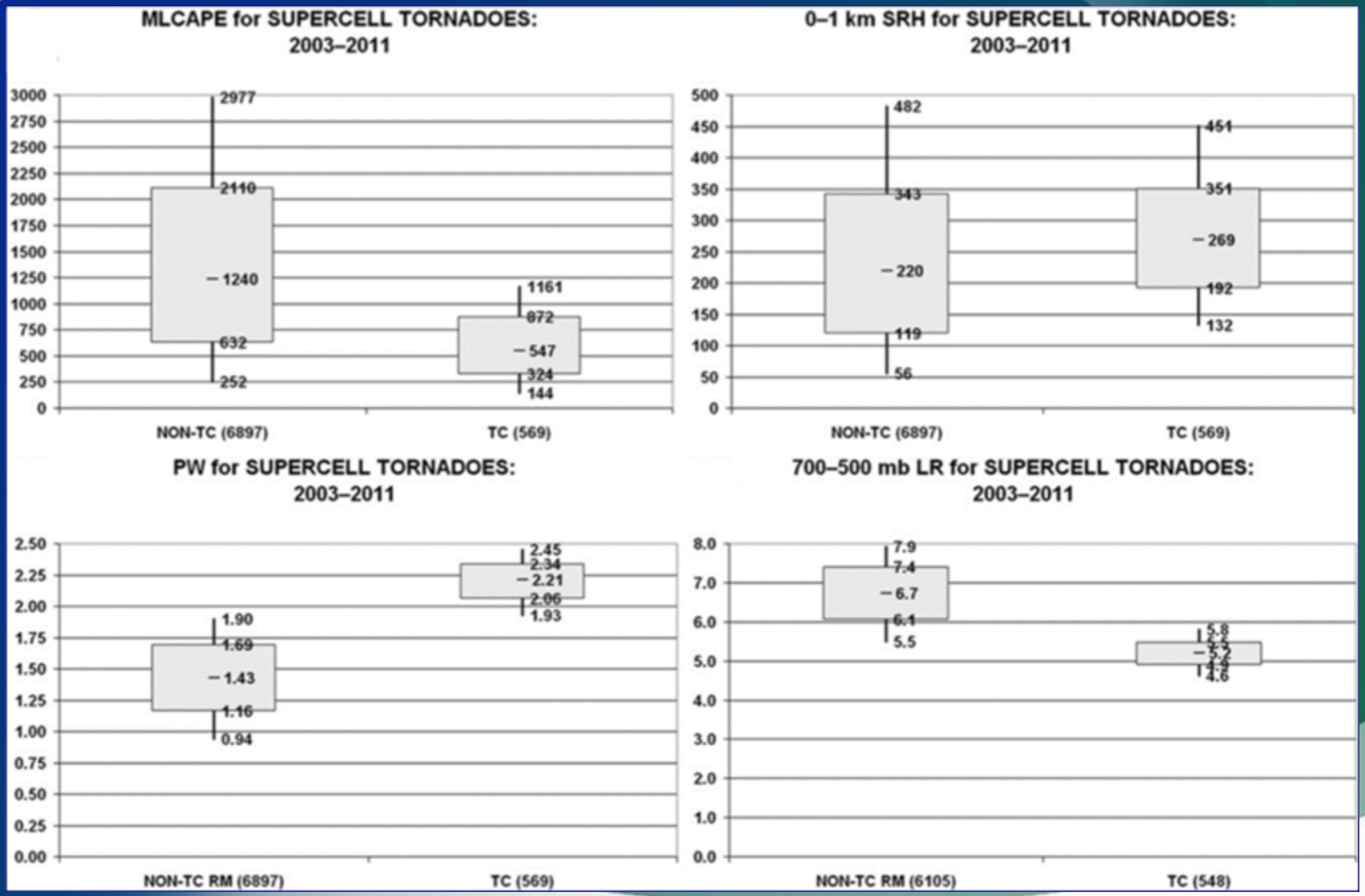
TC TORNADO FORECASTING CONCEPTS

Objectively analyzed parameters (e.g. SPC SFCOA)

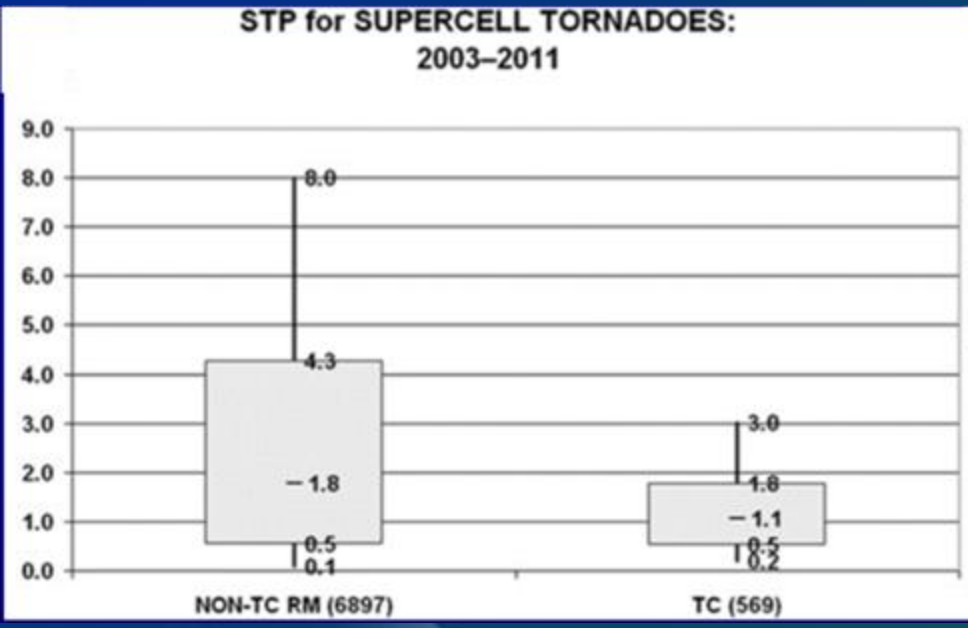
- TESTED FOR 2003-2011 TC TORNADO ENVIRONMENTS
- LITTLE DIFFERENCE WITH ANY PARAMETER between WEAK & STRONG TC TORNADOES
- HIGH PW, WEAK LAPSE RATES, LOWER MLCAPE WITH TC vs. MIDLATITUDE TORNADOES
- LOWER/MORE COMPRESSED SCP AND STP DISTRIBUTIONS FOR TC TORNADOES
- RUC-BASED: WAS UNRELIABLE/INACCURATE WITH WIND AND PRESSURE TOWARD CENTER OF TS AND HURRICANE. TOO FEW CASES on RAPID REFRESH.

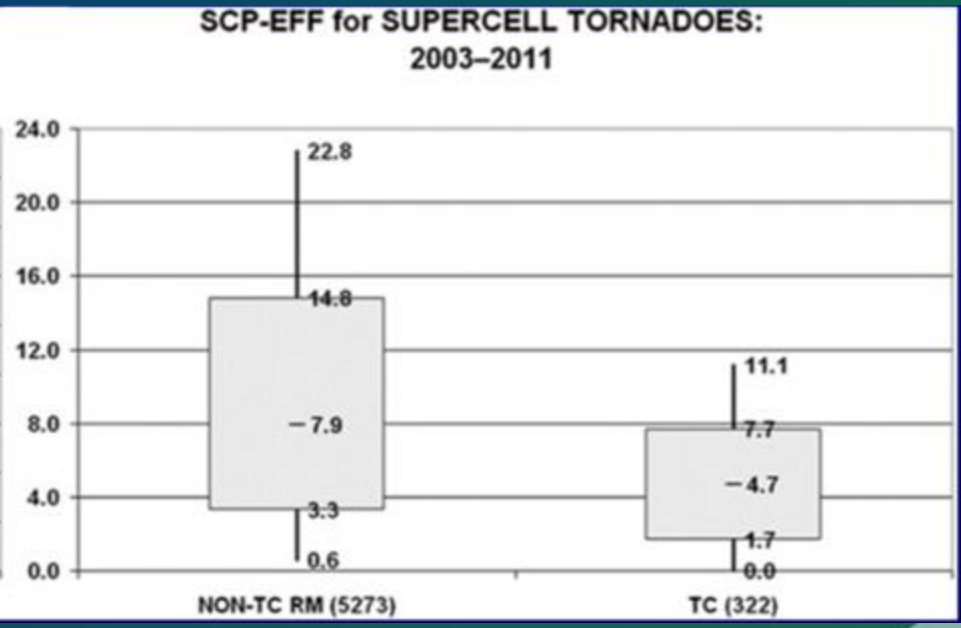
Edwards et al. 2012

TC TORNADO FORECASTING CONCEPTS



TC TORNADO FORECASTING CONCEPTS



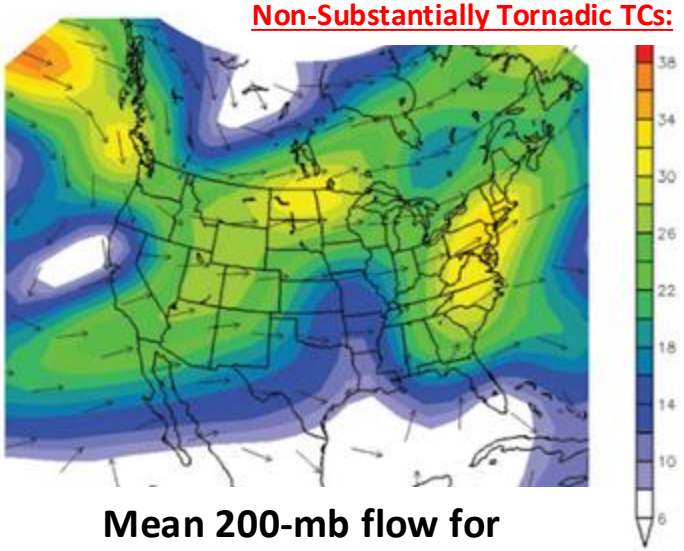


TC TORNADO FORECASTING CONCEPTS

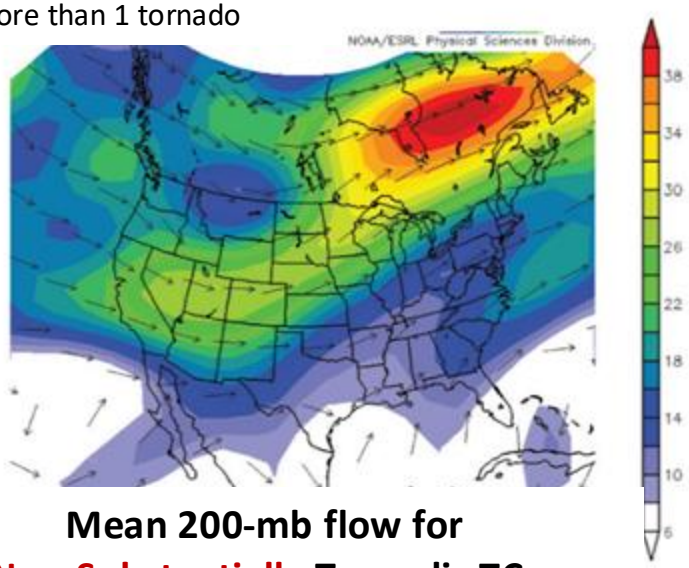
TC TORNADO FORECASTING CONCEPTS – SYNOPTIC PATTERNS

Substantially Tornadic TCs: Produce at least 4 tornadoes
Non-Substantially Tornadic TCs: Produce no more than 1 tornado

Fig. 3(c).



Mean 200-mb flow for
Substantially Tornadic TCs



Mean 200-mb flow for
Non-Substantially Tornadic TCs

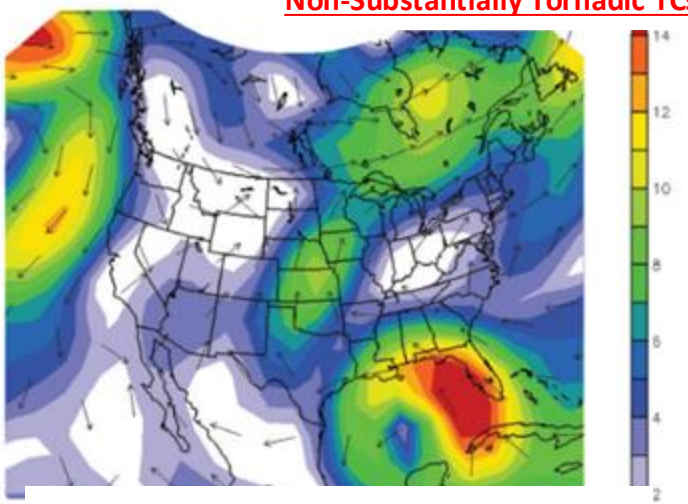
-Right entrance region of enhanced 200-mb jet streak enhances tornado potential over Southeast.

-Any upper-level jet streak associated with non-substantial tornadic TCs was much weaker.

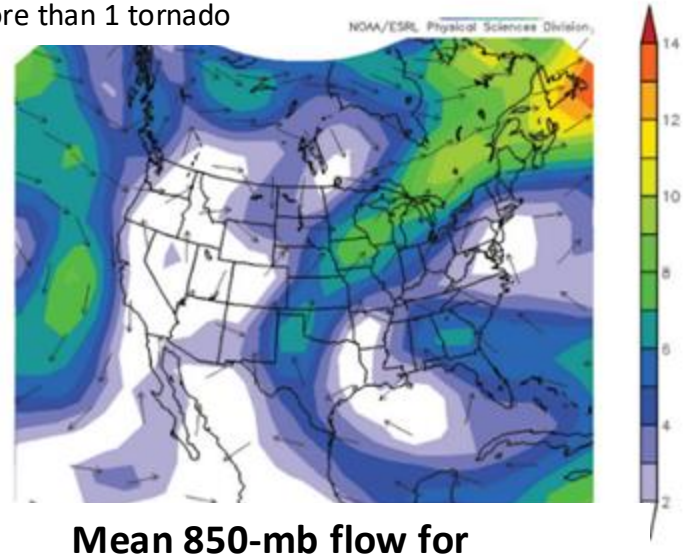
TC TORNADO FORECASTING CONCEPTS – SYNOPTIC PATTERNS

Substantially Tornadic TCs: Produce at least 4 tornadoes
Non-Substantially Tornadic TCs: Produce no more than 1 tornado

Fig. 4(c).



Mean 850-mb flow for
Substantially Tornadic TCs



Mean 850-mb flow for
Non-Substantially Tornadic TCs

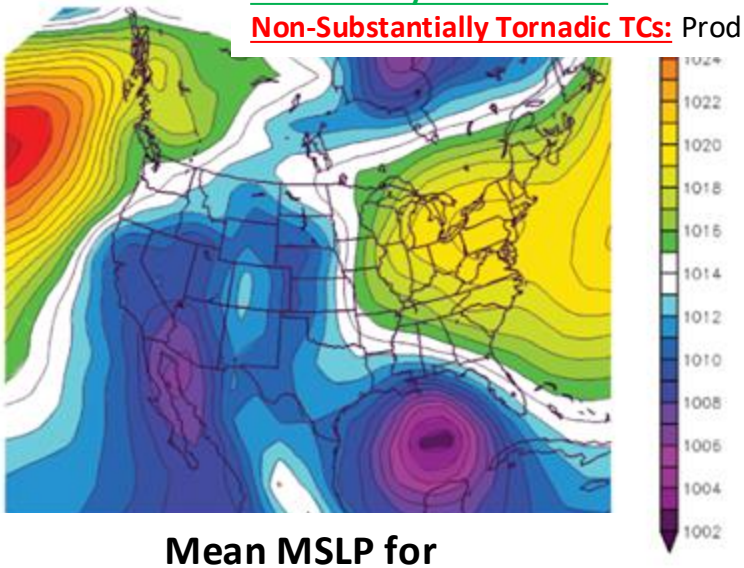
-850-mb flow field -- associated with subst. tornadic TCs -- well organized, large, and directionally-symmetric, with strongest flow in NE semicircle of cyclonic flow envelope

-In this region, SRH will be maximized, enhancing tornadogenesis potential

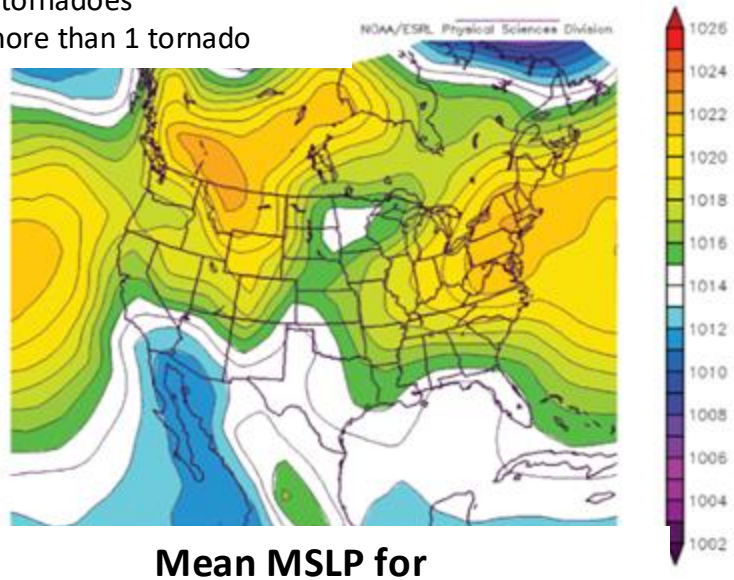
TC TORNADO FORECASTING CONCEPTS – SYNOPTIC PATTERNS

Fig. 5(c).

Substantially Tornadic TCs: Produce at least 4 tornadoes
Non-Substantially Tornadic TCs: Produce no more than 1 tornado



Mean MSLP for Substantially Tornadic TCs



Mean MSLP for Non-Substantially Tornadic TCs

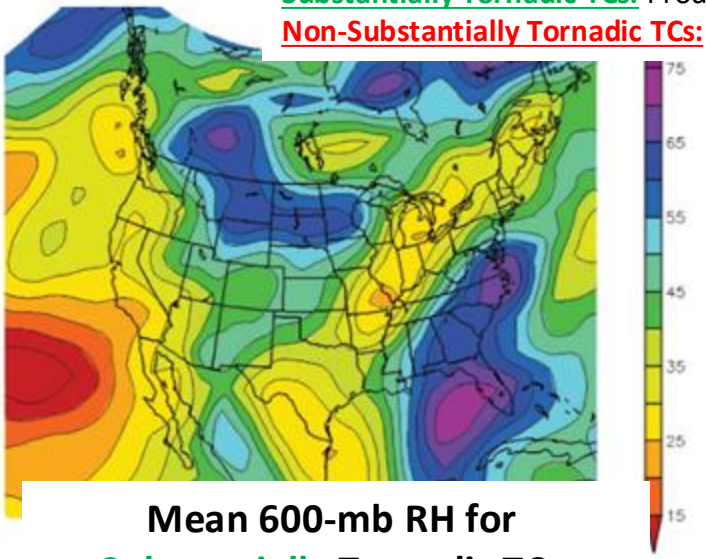
-The area of low pressure associated with subst. tornadic TCs well-defined and symmetric, as opposed to a broad trough

-Pressure gradient maximized in NE semicircle. In this region, SRH will be maximized, enhancing tornado potential

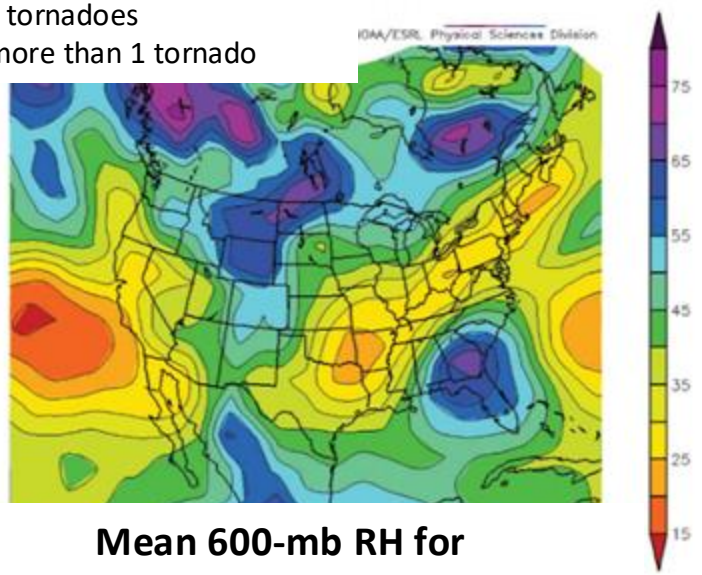
TC TORNADO FORECASTING CONCEPTS – SYNOPTIC PATTERNS

Fig. 6(c).

Substantially Tornadic TCs: Produce at least 4 tornadoes
Non-Substantially Tornadic TCs: Produce no more than 1 tornado



Mean 600-mb RH for Substantially Tornadic TCs



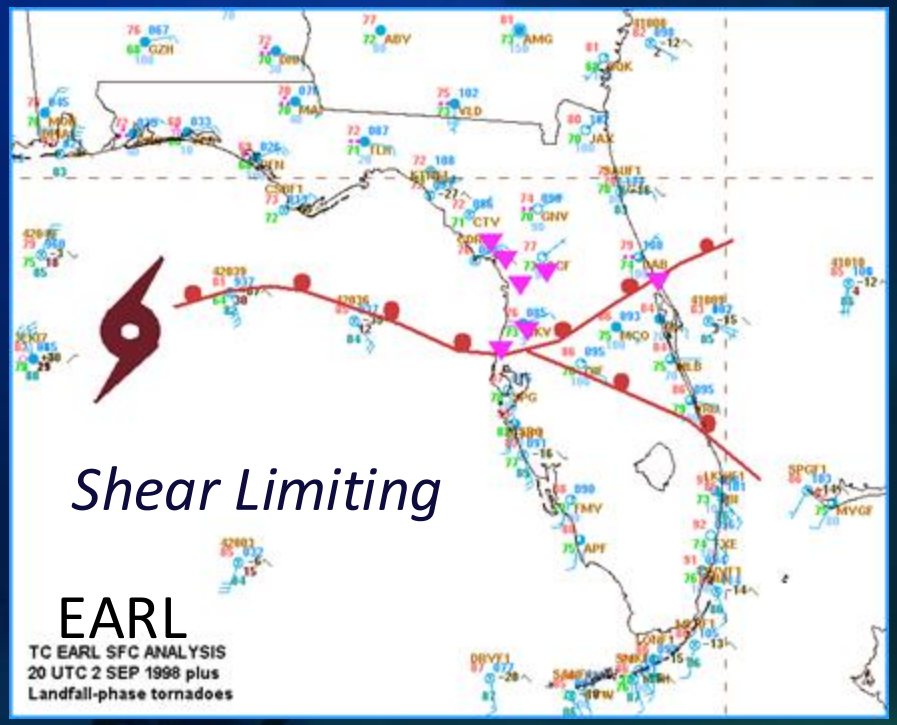
Mean 600-mb RH for Non-Substantially Tornadic TCs

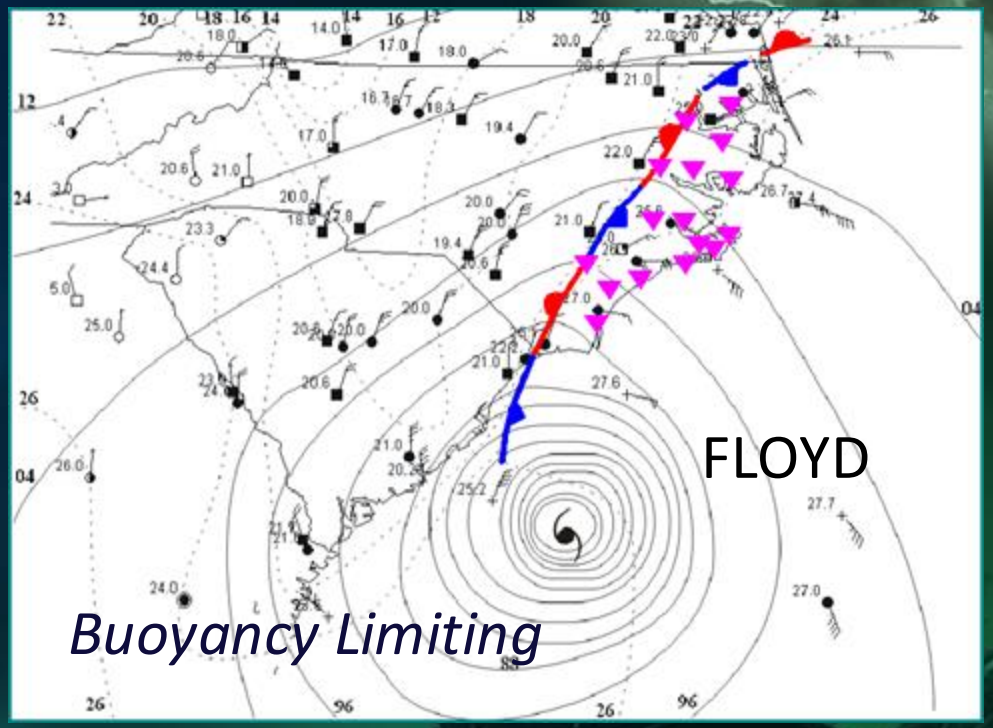
-Presence of a spatially-broad, yet strong, horizontal gradient in mid-level moisture is found over NW semicircle of cyclonic flow envelope

-Dry air driving this gradient enhances low-level buoyancy in vicinity of rain bands through mid-level dry air entrainment into the TC

TC TORNADO FORECASTING CONCEPTS – MESOSCALE BOUNDARIES

Baroclinic and wind boundaries can influence threat



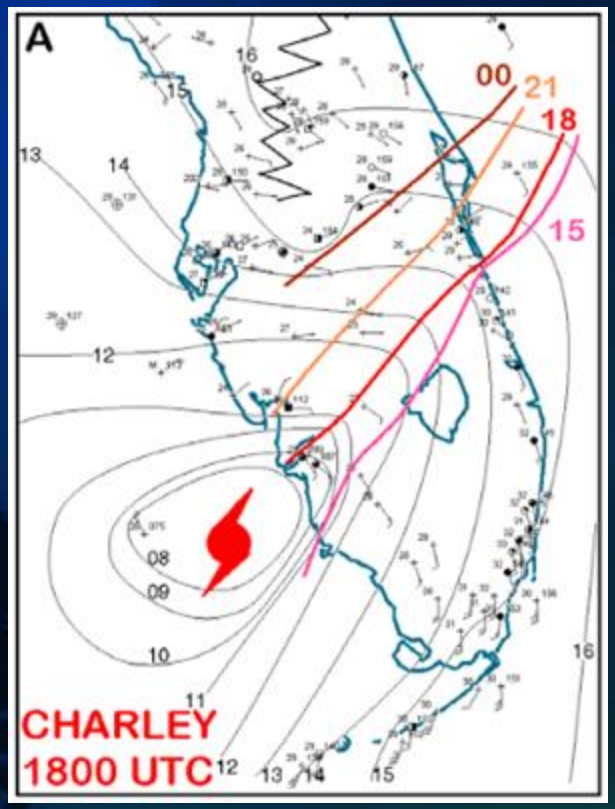


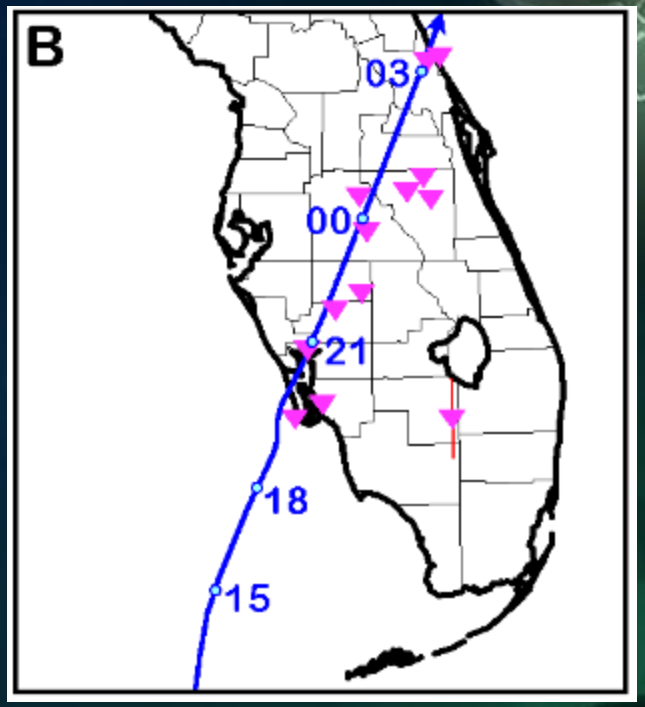
Favorable buoyancy on both sides, only favorable shear on cool side.

Favorable shear on both sides, only favorable buoyancy on warm side.

Edwards and Pietrycha 2006

TC TORNADO FORECASTING CONCEPTS – MESOSCALE BOUNDARIES



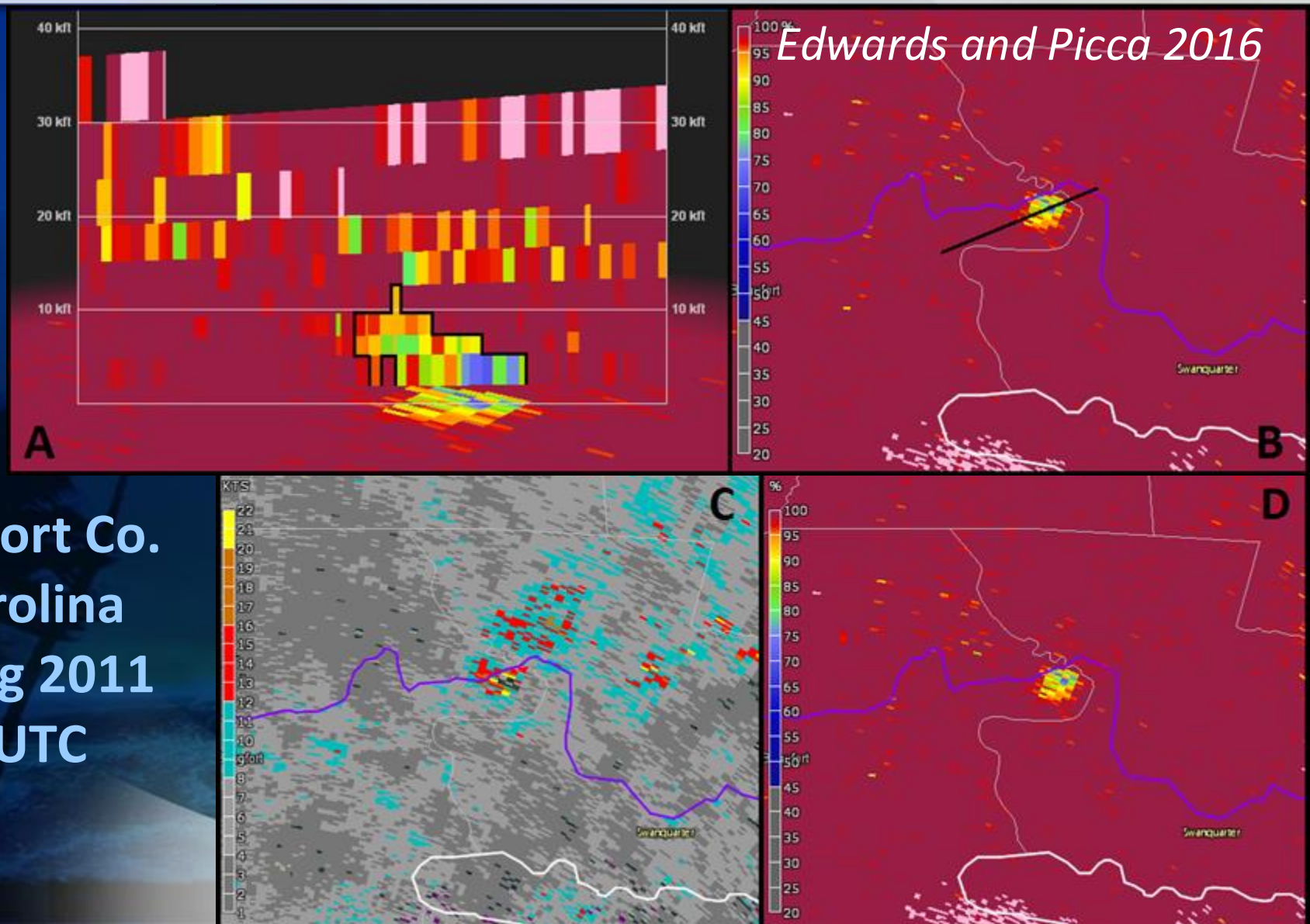


Buoyancy-Shear Overlap

Favorable buoyancy on one side, favorable shear on the other. (Slim corridor of overlap near the boundary)

Edwards and Pietrycha 2006

RADAR CONCEPTS for TC TORNADOES



Edwards and Picca 2016

Beaufort Co.
N. Carolina
27 Aug 2011
0203 UTC

RADAR CONCEPTS for TC TORNADOES

Tornado Warned Supercell

near Norge OK **TC**

Erin

PAR VCP 12 60° sector

0.5° oversampling in azimuth

Interval ~ **43 s**

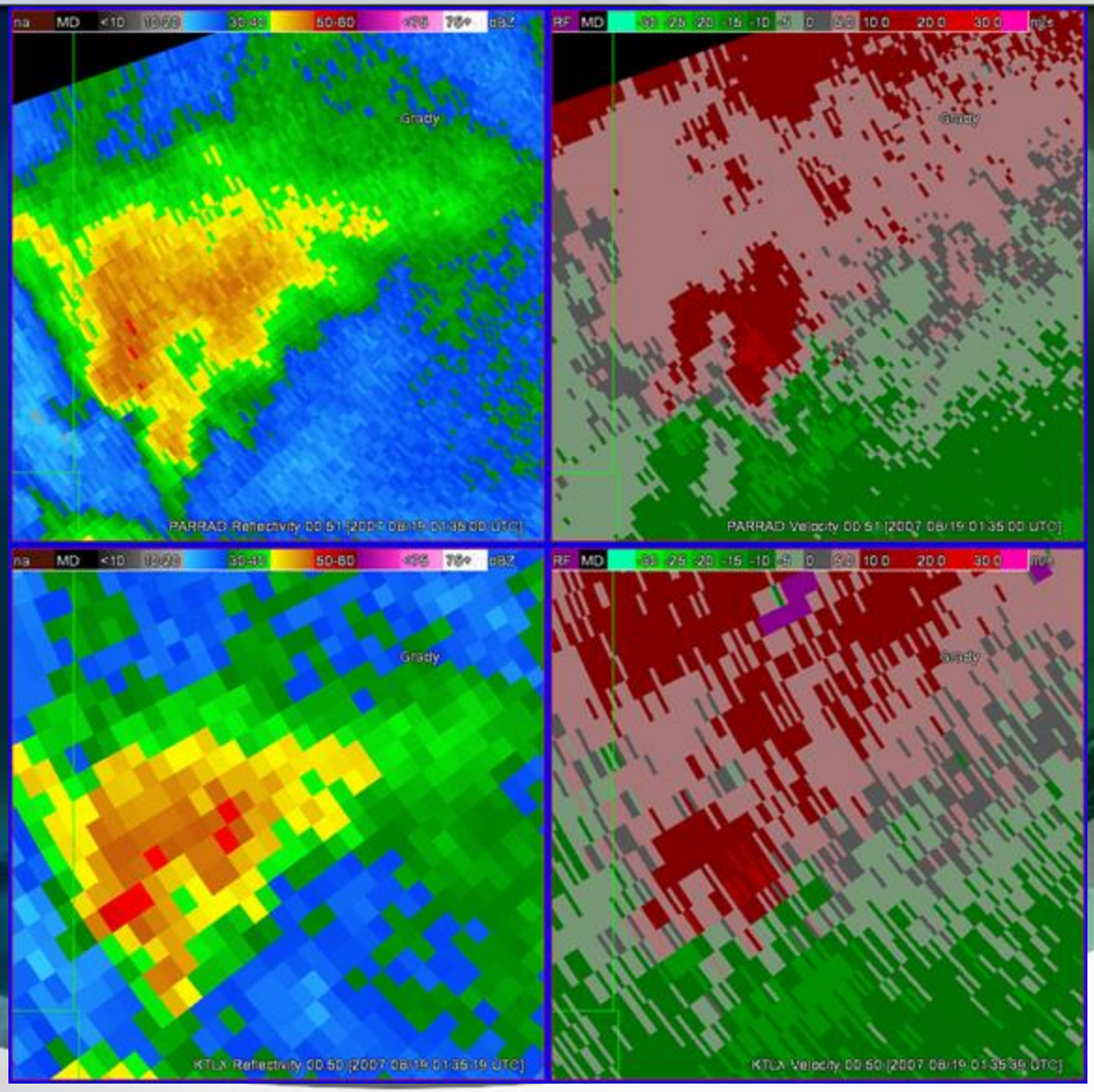
19 Aug 2007

0135-0154 UTC

WSR-88D

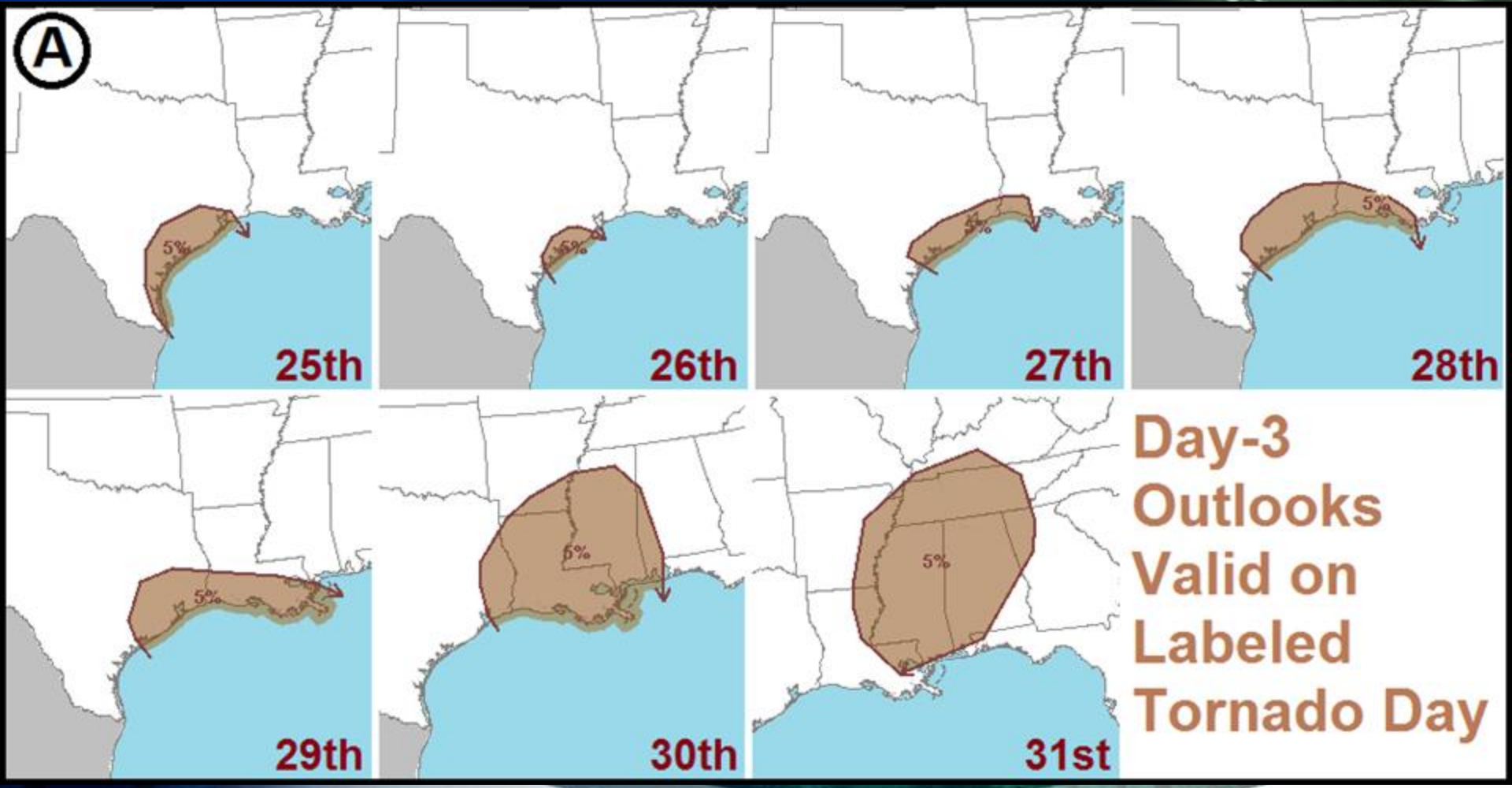
VCP 12

Interval ~ **4.1 min**



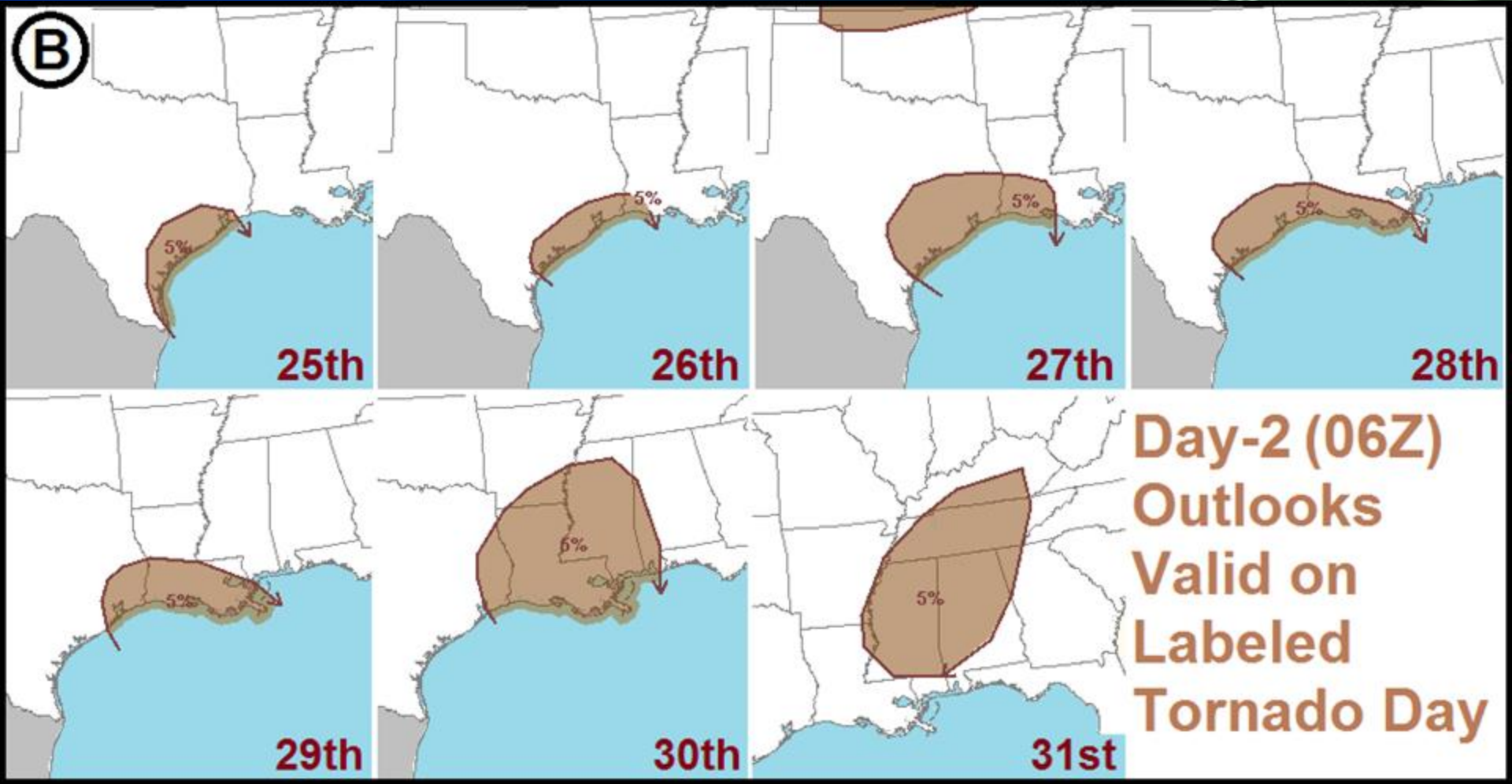
SPC FORECAST EXAMPLES FOR TCs

OUTLOOKS (Day-3 examples for HARVEY)



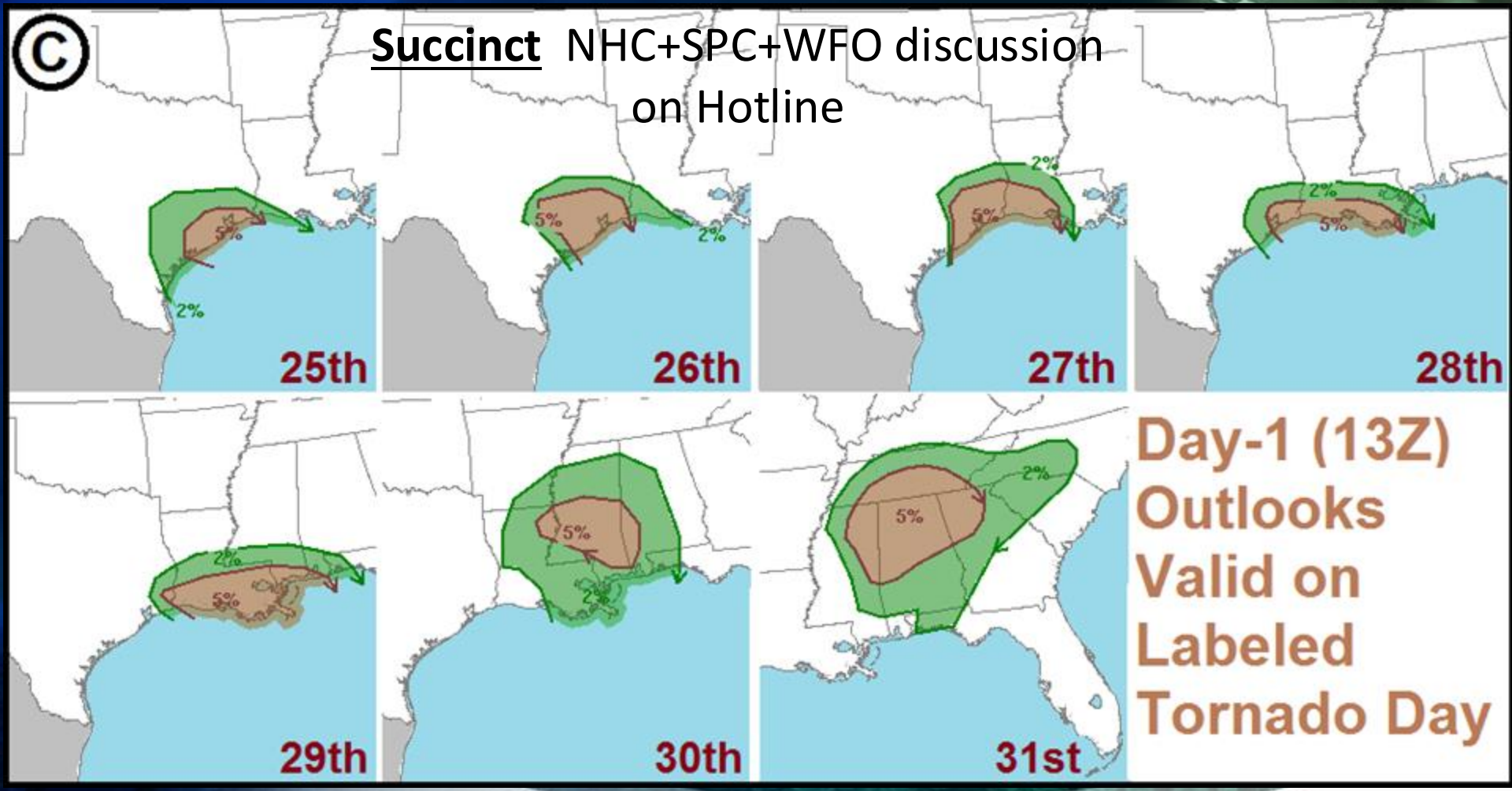
SPC FORECAST EXAMPLES FOR TCs

OUTLOOKS (Day-2 examples for HARVEY)

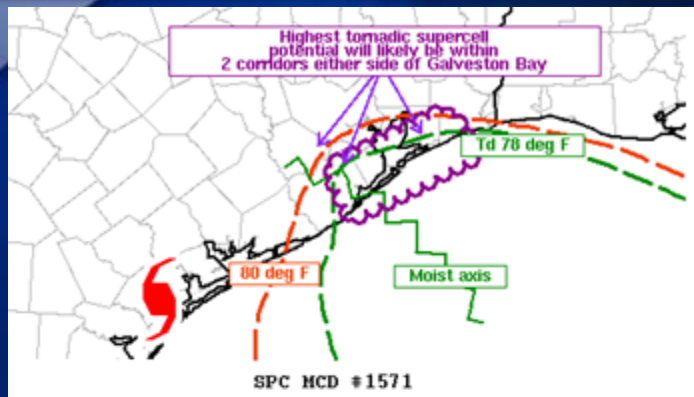


SPC FORECAST EXAMPLES FOR TCs

OUTLOOKS (Day-1 examples for HARVEY)



SPC FORECAST EXAMPLES FOR TCs



SPC MCD #1571

Mesoscale Discussion 1571
NWS Storm Prediction Center Norman OK
0117 AM CDT Sat Aug 26 2017

Areas affected...Upper Texas Coast

Concerning...Tornado Watch 465...

Valid 260617Z - 260645Z

The severe weather threat for Tornado Watch 465 continues.

SUMMARY...The highest potential for tornadic supercells will likely be within 2 corridors either side of Galveston Bay (Brazoria/Fort Bend and Chambers Counties) for the next 1-2 hours. A new tornado watch will be issued before 0700 UTC.

DISCUSSION...Latest subjective surface mesoanalysis indicates the 80 degree F isotherm encompasses Brazoria county northeast into Chambers county. The northwest area of a plume of 78 degree F dewpoints protrudes northwest from the northwest Gulf of Mexico into the immediate coastal area of Brazoria county. The latest RAP forecast sounding appears to be representative of the surface and around 1400 J/kg MLCAPE is noted. When inputting storm motion (135 degrees at 35-kt), the KHGX VAD indicates around 200 m2/s2 0-1 km SRH. With robust updrafts implied by the convective structures (echo tops 35-40k ft), the environment will continue to be favorable for low-level mesocyclones and a tornado risk over the next 1-2 hours.

..Smith.. 08/26/2017

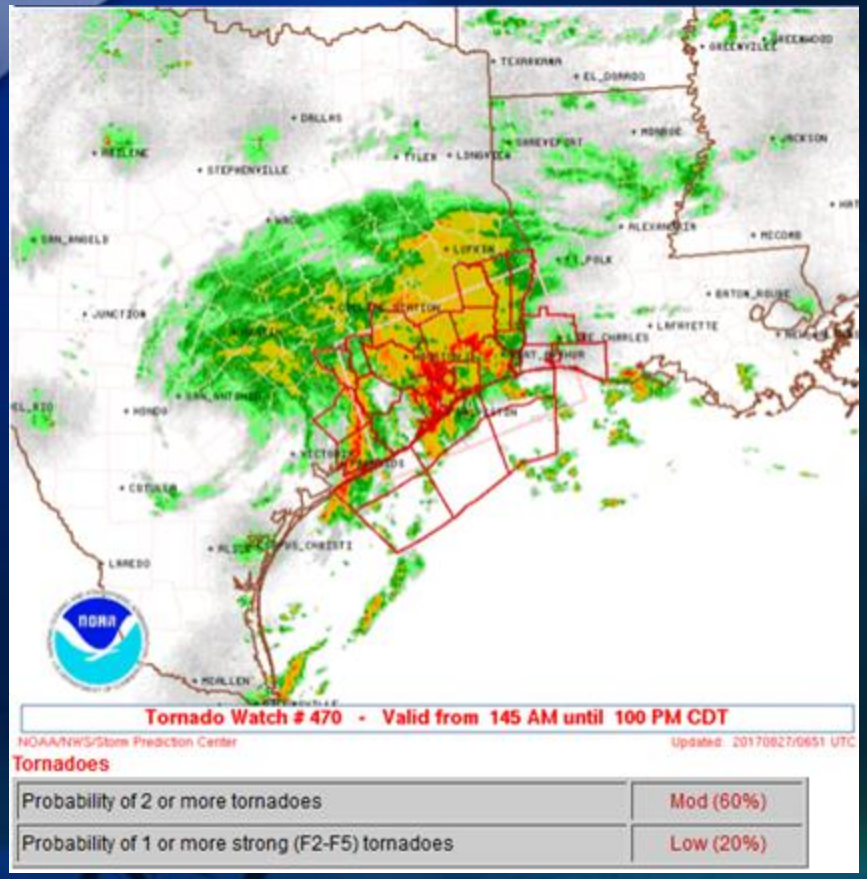
MESOSCALE DISCUSSIONS

Example:
HARVEY (2017)

Issued for watch potential or watch updates

Situational, no deadlines nor rigid thresholds

SPC FORECAST EXAMPLES FOR TCs



Example from Harvey (2017)

WATCHES

- Coordinated SPC+WFO
- County based
- Cleared/extended by WFO
- Legacy polygon for aviation
- Tornado probabilities offered with watch
- Targeted to situational tornado threat
- Not necessary for all TCs. ***Some TCs don't produce tornadoes!***